As a result of this allergic reaction, bacilli of reinoculation are for the most part held at the point of implantation, and if the numbers are relatively small the infection which takes place usually proves to be abortive. This is probably the greatest defensive factor that we have in chronic tuberculosis during the early period of dissemination.

It is probable that immunity is something different from sensitization of cells and allergy; at the same time it is also probable that sensitization and allergy are states which are a part of, which precede and which lead up to the ultimate establishment of immunity.

Primary infection of the lung is necessarily of exogenous origin. It may be that the bacilli enter through the air passages, or through the gastrointestinal tract. The theory of the former method has the most adherents; but those who adhere to the latter call attention to the fact that if bacilli gain entrance to the body through the alimentary canal and pass through the intestinal wall, they immediately enter the lymph channels, are poured into the thoracic duct, and thence into the subclavian vein going to the heart, and on through the lesser circulation. So the first opportunity for implantation would be in some portion of the lesser circulation. Entering virgin soil, as the bacilli which form the primary inoculation do, they meet no specific tissue resistance; but entering immune soil, as the bacilli of reinoculation do, they meet the resistance produced by cell sensitization, and a tissue response in the form of allergic inflammation. This protection becomes so great after infection has been present for some time that bacilli can enter the tissues from without only with great difficulty, or when the specific protection has been lowered. So after infection has once taken place the endogenous source of inoculation is much more plausible than the exogenous.

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Robert A. Peers, M. D. (Colfax).—Doctor Thomas, in his paper, and Doctor Pottenger, in the discussion, have covered the fundamentals of the cellular reaction to first and to subsequent invasions of tubercle bacilli. Further discussion of the point would lead merely to elaboration of details.

In considering, however, the two questions which Doctor Thomas formulates at the beginning of his paper, one must recognize other factors involved besides those of allergy or immunity. True, there is in all of us a certain amount of natural immunity, a greater or lesser amount of inherited cellular, or humoral immunity, or both, which gives each of us greater or lesser resistance to the invasion, and to the multiplication and extension to other parts of the organism of the tubercle bacillus. This natural immunity or lack of immunity is undoubtedly a factor in the determination of which infected child develops clinical tuberculosis, and also in the determination of which of those with clinical tuberculosis will fail to recover.

Again the question of dosage plays a part in the outcome of the process which follows implantation. A large dose of bacilli received from the careless tuberculous father or mother is, other things being equal, more dangerous to the child than a small dose of bacilli. Many bacilli furnish the exciting cause for many primary tubercles in first infections. Many bacilli, in secondary infections, furnish the medium for many isolated foci of allergic response. Immunity is a relative term. The greater the dosage of bacilli the more probable this immunity will be overcome.

Accident, as Krause has pointed out, also plays a part in the determination of the result of infection. Some tissues are more suited to hold and fix the bacilli than are others. Thus the accident of location of the first tubercle plays quite a part in retention or extension. The same is true in secondary infection whether endogenous or exogenous. The accident of the rupture of a solitary caseating lymph node into a blood vessel or into the thoracic duct with the production of an acute miliary tuberculosis may furnish the answer to these questions. Or again, the accident of extension to the meninges of the brain and cord of an already allergic child causes symptoms and results due to the allergic response of exudation quite different from those experienced in the more fortunate individual whose allergic response occurs in the lungs.

As Doctor Pottenger states truly, "In order to understand tuberculosis as a clinical disease it is necessary to understand what takes place at the time of the primary infection."

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Harold K. Faber, M. D. (Stanford University Medical School, San Francisco).—Discussion of the subject of Doctor Thomas's paper would be incomplete without mention of three common clinical manifestations of immunobiologic reaction to tuberculosis—erythema nodosum, phlyctenular keratoconjunctivitis, and the so-called epituberculous lesion of the lung. All these coincide in a large majority of cases with a period of violent reactivity to tuberculin, and are regarded by good authorities as effects of tuberculin itself. The literature on erythema nodosum in relation to tuberculosis is quite extensive. The work of Ernberg [1] and of Wallgren [2] may be cited. Casparis [3] has recently discussed the relation of phlyctenular lesions to tuberculosis. Eliasberg and Neuland's [4] paper may be consulted for a discussion of the epituberculous infiltrations of the lung. Another paper of Wallgren's [5] discusses the clinical manifestations of tuberculin allergy in infants and children in considerable detail.

It has perhaps been too seldom appreciated by the medical profession at large that the development of allergy to tuberculin is accompanied in many instances by rather stormy symptoms and fairly characteristic signs or radiographic changes, which can often be recognized by careful study, and Doctor Thomas, in calling attention to the fact, is performing a useful service.

1 Jahrb. f. Kinderheilk., 1921, 95, 1.
2 Jahrb. f. Kinderheilk., 1927, 117, 313.
3 Am. Jour. Dis. Child., 1927, 34, 779.
4 Jahrb. f. Kinderheilk., 1921, 94, 102.
5 Am. Jour. Dis. Child., 1928, 36, 702.

FREE FASCIAL GRAFTS—THEIR UNION WITH MUSCLE*

REPORT OF CASES

By S. L. Haas, M. D.
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Discussion *by John Hunt Shephard, M. D., San Jose; Leo Eloesser, M. D., San Francisco; Sterling Bunnell, M. D., San Francisco.*

A number of operative procedures, particularly the cure of hernia, depend upon the principle that fascia will unite with muscle.

OBSERVATIONS OF SEELIG AND CHOUKE

In spite of the large number of successful hernia operations, Seelig and Chouke [1] concluded from their observations on recurrences after herniotomy that fascia will not unite with muscle. To further substantiate their claims they performed a series of experiments on animals in which they reduplicated the fascia lata to simulate Poupart's ligament and sutured the edge of the turned flap to the underlying muscle. In

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* Read before the General Surgery Section of the California Medical Association at the fifty-eighth annual session, May 6-9, 1929.

every instance they found that the fascia lata was separated from the muscle by a loose areolar tissue. If the muscle was traumatized by the excision of a wedge and the fascia sutured to the raw muscle, there was an attempted union which was complete in only one instance. When a pedicle flap was passed through a tunnel in the muscle, they found that at the places where the fascia came into contact with intramuscular connective tissue (perimysium) it fused and became firmly anchored. Where the perimysium was scanty, however, the fascia strip lay in its tunnel with practically no evidence of union. They claimed that it was useless to suture the internal oblique and transversalis muscles to Poupart's ligament because they would fail to unite unless the muscles had been vigorously traumatized. If they did unite it would not be permanent because of the inevitable tension that would occur when these structures were approximated.

EXPERIMENTS OF KOONTZ AND OTHERS

Naturally these rather sweeping assertions aroused considerable interest and discussion, from the clinical as well as from the experimental standpoint. Koontz [2] was one of the first to further investigate this important subject. In 1926, in a paper entitled "Muscle and Fascia Suture With Relation to Hernia Repair," he gave the results of his experiments on dogs. He endeavored to imitate an ordinary hernia repair, except that there was no sac to tie off, making the suturing of the internal oblique to Poupart's ligament the main feature of the operation. He obtained firm union in every instance. Koontz repeated the experiments of Seelig and Chouke, elaborating upon them to the extent of removing, on one side, the loose areolar tissue from the undersurface of the fascia lata, while on the opposite side of the animal it was not disturbed. The experiments in which the areolar tissue was removed resulted in firm union with the underlying muscle, while in those in which it remained there was no union. It was claimed that the failures of Seelig and Chouke were due to the fact that they did not remove this thin layer of areolar tissue.

Seelig and Chouke [3] independently repeated their previous experiments, scraping the adipose layer from the fascia lata, as they had done in their first experiments, but had failed to state specifically in their article. They obtained the same results as in the first instance, namely, that the reduplicated fascia failed to unite with the muscle.

Rosenblatt and Cooksey [4] made the same experiments that Seelig and Chouke had found unsuccessful and obtained exactly opposite results. They found, as had Koontz, that in the cases where they removed the areolar tissue from the fascia there was a firm union, while in those where it was allowed to remain there was but a slight union. They also sutured the rectus muscle to Poupart's ligament after removing the loose areolar tissue, and secured firm union in every instance.

It is difficult to explain the discrepancies in the results obtained by these investigators who performed the same experiments with the same technique. Hertzler,[5] in commenting on these differences, offered the following suggestions, using his experiments and clinical observations as the foundation for his opinions. He found, in studying the healing of wounds, that the proximity of any fat-bearing tissue prevented the process of regeneration because fibrin bundles could not form in the presence of fat. He stated that it was the traumatic reaction which actuated the fibrin formation. This in turn resulted in the generation of fibrous tissue which performed the union. Therefore, he claimed, to obtain a union between Poupart's ligament and muscle the sutures must be tied tightly enough to traumatize the muscle. He believed that the difference in the results obtained by Seelig and Koontz was due to the fact that Seelig made his sutures loose while Koontz made his very tight. The preponderance of proof, however, seems to favor the positive findings that a union does take place between fascia and muscle.

Regardless of this belief that muscle and fascia will unite there have been a number of recurrences after herniotomies. Because of these circumstances, some supplementary method of operation was sought which would give more satisfactory and lasting results. This was achieved by Gallie and Le Mesurier by using fascia in the repair of hernia. It is also to be noted that McArthur [6] as early as 1901 had utilized strips of the tendinous portion of the external oblique muscle for suture purposes in hernioplasty. He found, experimentally, that the tissue healed *in situ* without absorption or sloughing.

TRANSPLANTATION OF FASCIA

The transplantation of fascia was placed on a firm clinical basis by Kirschner [7] twenty years ago. There has always been, however, some doubt as to whether this transplant survived as such, or whether it was replaced by ingrowing tissue. A vast amount of experimentation has been done on this subject, some of which will be reviewed, briefly, in this paper.

Kleinschmidt [8] found, as a result of his work, that grafts placed under the skin showed little replacement while those put into muscle defects and subject to tension showed alterations in thickness, partial disappearance of portions not under tension, and partial replacement.

Kornew [9] observed similar changes and found that fascia transplanted into defects in a tendon was transformed into a fibrous tissue intimately interwoven with and practically indistinguishable from the tendon.

Gallie and Le Mesurier [10] found that a reimplanted piece of fascia lata showed practically no change and remained alive. In the early stages there was a little inflammatory edema which disappeared in three weeks, while in specimens examined after a year there was nothing to indicate that the cells or fibers had changed in any way. These two men emphasize the importance of removing the areolar tissue, because if it be allowed to remain the strength of the union will not exceed that of the fat tissue. As a result of their work the use of fascia suture in hernia repair has become a successful clinical procedure.

Neuhoff [11] concluded from his experiments that the transplanted fascia was not preserved as such but was gradually replaced by fibrous connective tissue which closely resembled the fascia. He believed that the replacement was gradual and often might not be complete a year after the operation. The end result appeared to be a cellular connective tissue which occupied the framework and largely maintained the form of the original graft.

The proof of permanent viability of the graft has not been established. The replacement phenomena are of very gradual evolution, the size of the graft is maintained and the result and purpose for which the transplantation has been performed is ordinarily achieved.

The clinical applications of transplanted fascia cover a wide field in surgical practice. It is sufficient, however, to call attention to its uses as suture material in herniotomy, in joint capsule repair, filling in dura and pleural defects, ventral hernia, the repair of hollow viscera and the organs of the body, arthroplasty, and in tendon and muscle repair, to indicate its clinical significance.

USE OF PRESERVED FASCIA

These and other applications of transplanted fascia were followed by the institution of the use of preserved fascia as a surgical procedure. This development was stimulated by the work of Nageotte and Sencert.[12] Nageotte, as a result of his experiments, concluded that the fibers of connective tissue were inert coagula formed from living cells, and that when these were transplanted after preservation they did not act as a foreign body. The preservation did not change either their physical or chemical characteristics because they were lifeless in the animal just as they were in the alcohol. The dead cells of the graft were indistinguishable from the normal tissues.

Koontz,[13] in a series of experiments, found that fascia preserved in alcohol and then transplanted into a defect in fascia intermingled so closely that it was almost impossible to distinguish the dead from the living tissue. Heterografts took just as well as homografts. Because of the success which he attained in his experimental work he felt justified in utilizing preserved fascia for the cure of hernia in man. He followed, in general, the method used by Gallie and Le Mesurier [10] in applying the preserved fascia lata of the ox for suture material in hernia repair, and obtained successful results.

Rosenblatt and Meyers [14] performed a series of experiments in which they sutured the edge of the rectus muscle to Poupart's ligament with preserved ox fascia and tendon sutures. The muscle united firmly with Poupart's ligament. By that time the preserved fascia sutures appeared slightly smaller than at the time of the operations, and there was some evidence of foreign body reaction. This absorption and foreign body reaction of the transplanted preserved fascia is contradictory to the findings of Nageotte and Koontz.

It would not have been surprising if a dispute had arisen regarding the union of transplanted fascia with muscle, because in cases of this kind the conditions are entirely different from those in which the tissues to be united are in their normal environment with their nerve and blood supply intact. Where transplanted fascia is utilized its vitality is affected by the severance of its normal blood and nerve supply and its power to proliferate is accordingly diminished. However, although Nageotte claims that fascia is an inert tissue, we know that healing does occur when fascia is sutured to fascia in the repair of a wound, or when a fascial transplant is placed in a fascia defect.

WHAT CONSTITUTES UNION BETWEEN FASCIA AND MUSCLE

The question may arise as to whether or not the muscle cells are expected to take an active part in uniting the muscle with the transplanted fascia. In order to create uniform criteria and avoid confusion, it seems advisable to state definitely what is to be interpreted as constituting a union between fascia and muscle. The muscle cells or fibrils, which are arranged in bundles and groups of bundles, are highly specialized and possess limited powers of proliferation and regeneration. On the other hand, the connective tissues which surround the muscle's cells and fibrils and the muscle's bundles (respectively, endomysium and perimysium) are nonspecialized and do possess the properties of active proliferation. Because of this fact they quite naturally would be expected to play the major rôle where a reparative response is necessary. However, regardless of whether it is the connective tissue elements or the muscle cells themselves which are most actively engaged in the process, a union between muscle and transplanted fascia is considered successful whenever the two tissues are intimately and completely united.

EXPERIMENTS MADE IN THIS STUDY

The stimulus for the work, which will be reported presently, on the subject of transplanted fascia was produced by the institution of the Mayer operation.[15] This procedure depended upon the ability of a piece of transplanted fascia lata to unite with a raised portion of the trapezius muscle.

In order to study the results of suturing transplanted fascia to muscle, a series of six experiments were performed, under general ether anesthesia, upon dogs. In each of these experiments an incision was made on the outer side of the thigh through the skin and fat to the fascia lata, and a section of fascia of the desired length and width removed for use as a free graft. This was followed by a second incision which exposed the tendons of either the semitendinosus or semimembranosus muscle on the inner side of the knee-joint. A section of muscle and tendon was then excised where the muscle merged into the tendon. A piece of folded free fascia graft was sutured into the gap which had been made between the belly of the muscle and the cut end of the tendon. The animals were killed under anesthesia after the desired time had elapsed and the specimens fixed for microscopic study.

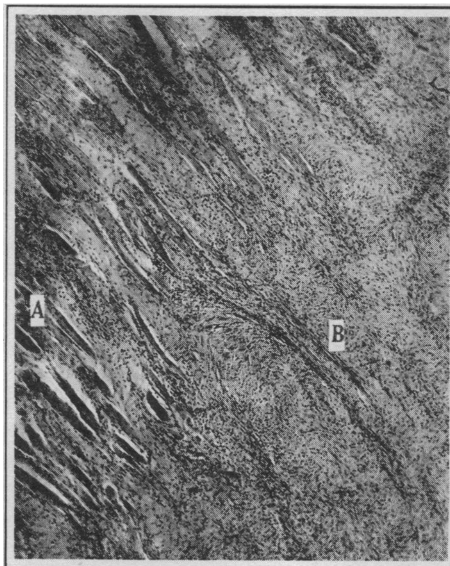

Fig. 1. (Experiment 1. Sixteen days).—Union of transplanted fascia lata with muscle. There is a close intermingling of the endomysium with the fascia. Notice the changes in the muscle fibrils. A. Muscle. B. Transplanted fascia.

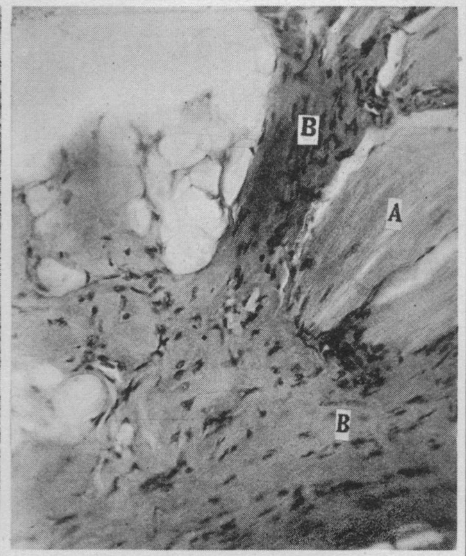

Fig. 2 (Experiment 3. Sixty-six days).—High magnification to show the changes in the muscle fibrils at the site of union. A. Muscle. B. Transplanted fascia.

Experiment 1.—Dog T4, left, sixteen days.

Operation.—A piece of fascia lata, from which the fat had been removed by scraping both surfaces with a scalpel, was taken from the outer side of the thigh. Through a second incision on the inner side of the leg, just above the knee-joint, the tendon of the semimembranosus muscle was exposed and severed at the point of its junction with the belly of the muscle. The piece of fascia was then attached with silk sutures to the muscle, on one end, and to the tendon on the other.

Gross Findings.—The fascia lata was found firmly united at its upper end to the muscle, and at its lower end to the tendon. It was impossible, even with the application of a considerable amount of force, to tear the transplanted fascia from the muscle. The fascia was swollen and somewhat edematous.

Microscopic Findings.—At that early period there was a close union between the transplanted fascia and the muscle, there having been a gradual transgression from one to the other. At the site of the union the muscle fibers were broken up. The cross striations were much less distinct and gave the muscle a hyaline-like structure. At the ends of the muscle fibers there was a marked multiplication of the nuclei, which appeared to be the result of the proliferation of the nuclei of the muscle fibrils themselves as well as of the endomysium. In places the ends of the muscle fibrils were broken up into strand-like areas which joined the fibers of the transplanted fascia. (Fig. 1). There was, likewise, an increase in nuclear elements of the fascia at the place of union. The transplanted fascia showed no evidence of degeneration. Some remnants of the transplanted fascia were found near the junction. One cannot say definitely, but it appeared that the muscle fibrils may have shared in forming the union between the muscle and the fascia. The endomysium (surrounding the muscle fibrils) and the perimysium (surrounding the bundles of muscle fibrils) most likely took the greatest part in the process, but there was evidence that the viable elements of the transplanted fascia had multiplied and shared in the fusion.

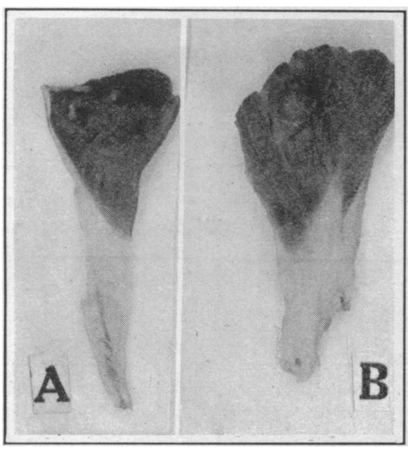

Fig. 3 (Experiment 6. Eighty-five days).—Gross specimens showing normal tendon (A) and artificial tendon (B) formed by suturing free fascia graft into muscle.

Experiment 2.—Dog 1, left, twenty-four days.

Operation.—A piece of fascia lata was removed from the outer side of the thigh. The tendon of the semitendinosus muscle was exposed and severed at the point of its junction with the muscle. The piece of fascia lata was sutured into the gap.

Gross Findings.—The fascia had healed in so well that the line of union was hardly discernible.

Microscopic Findings.—There was a closer and denser intermingling of the muscle and fascia at the line of union than was found at the earlier period. There were, as in the earlier stages, signs of the degeneration of the muscle ends, and, in places, fibrous strands extending into the fascia suggested that a direct attempt was being made by the fibrils to share in the union. The transplanted fascia appeared denser than in previous stages and was assuming a more tendinous structure. The vascularity of the tissue was increased.

Experiment 3.—Dog 5, left, thirty-six days.

Operation.—The semimembranosus tendon was exposed and a section of tendon and muscle was removed at the junction of the two. A piece of fascia lata was sutured into the gap.

Gross Findings.—The fascia was united firmly to the muscle. The fascia was spread out and appeared to have stretched.

Microscopic Findings.—At that stage there was a close penetration of one tissue into the other. There was, however, a noticeable amount of fat at the site of the union and upon the muscle. There was the same evidence as found in experiment two that the muscle was taking an active part in the union (Fig. 2). The fascia was transformed and appeared more tendinous than in the previous stage.

EXPERIMENT 4.—Dog 3, left, sixty-three days.

Operation.—The tendon of the semitendinosus muscle was exposed and severed just above its origin in the muscle, and again about two centimeters from its insertion. A piece of fascia lata was sutured into the gap.

Gross Findings. — The transplanted fascia was attached to the muscle on one side only.

Microscopic Findings.—There was a very close union of the fascia and muscle elements. In some places there was evidence of the direct outgrowth of the muscle fibers into the fascia. The transplanted fascia was dense in appearance and more tendinous than in earlier stages.

EXPERIMENT 5.—Dog 2, left, eighty-two days.

Operation.—The tendon of the semimembranosus was exposed and a section about one and five-tenths centimeters in length removed at the junction of the tendon and muscle. A folded piece of fascia lata was inserted into the gap and sutured, with silk, to the muscle at one end and to the tendon at the other.

Gross Findings.—The transplanted fascia was found united firmly to the muscle at the upper end and to the tendon at the lower. In general appearance it had assumed the likeness of a tendon.

Microscopic Findings.—The muscle and fascia were closely united. It was noticed that the muscle near the site of the union appeared unusually wavy, a condition which suggested a transformation into tendon. The cross striations were still present in the muscle that had acquired this wavy structure. The transplanted fascia was denser than in the earlier stage and appeared tendinous.

EXPERIMENT 6.—Dog 5, right, eighty-five days.

Operation.—The semitendinosus muscle was exposed and a segment of muscle one and five-tenths centimeters in length was removed at the junction of the tendon and muscle. A piece of fascia lata was sutured, with silk, into the gap.

Gross Findings.—The fascia lata was found united firmly to the muscle and tendon (Fig. 3).

Microscopic Findings.—There was a very close intermingling of the muscle and fascia. The muscle had a slight wavy structure in places, but not to the pronounced degree of that found in the former experiment. In places there were collections of fat cells which were most likely transplanted with the fascia. The fascia resembled, somewhat, a normal tendon in histological appearance.

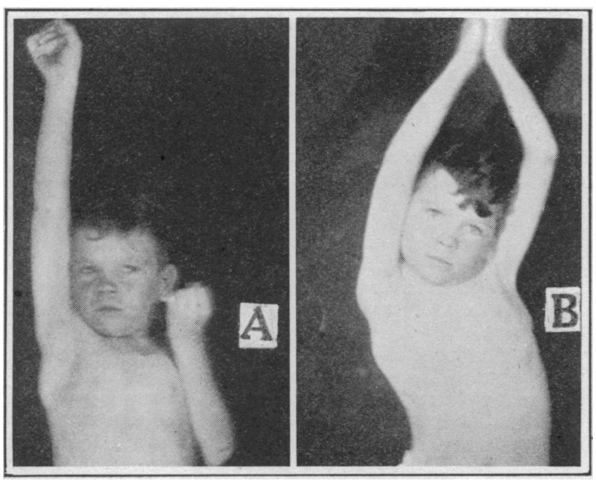

Fig. 4.—Patient from the Shriners' Hospital with paralysis of the deltoid muscle. A. Range of motion of the left arm before operation. Full abduction on the right. B. Showing almost complete abduction after the Mayer operation.

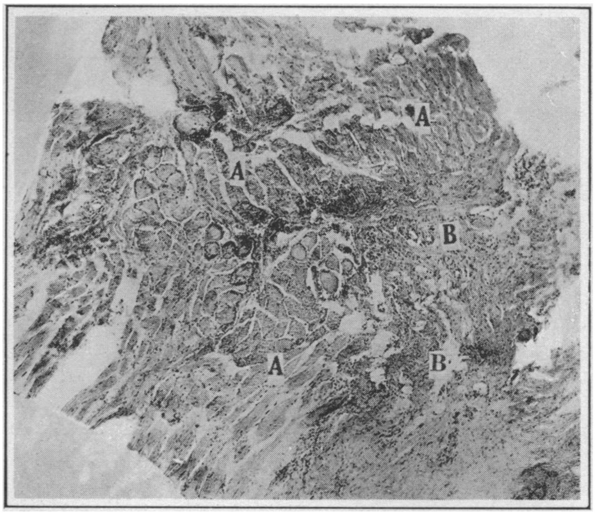

Fig 5 (Case 2).—Specimen removed from patient five months after Mayer operation. There is a close intermingling of the muscle with the transplanted fascia. Compare with Fig. 1 from experimental series. A. Muscle. B. Transplanted fascia.

CONCLUSIONS IN EXPERIMENTAL INVESTIGATION

On gross examination, evidence of strong union between the transplanted fascia lata and the muscle was found in every experiment.

It is difficult to determine definitely the exact part played by the various cellular elements of the fascia and muscle in forming the union. The connective tissue cells of the transplanted fascia showed definite evidence of viability throughout the experimental period. There was considerable evidence of proliferation of the cellular elements of the transplanted fascia at the site of the union. The endomysium and perimysium appeared to have contributed the greatest amount of tissue response in forming the union, while the muscle cells proper showed some cellular activity and possibly took a minor part in the process.

CLINICAL STUDY

According to Mayer, Lange claimed that transplanted fascia could not be used to construct an artificial tendon because the fascia would not unite firmly with the muscle fibers. Notwithstanding this declaration made by Lange, Payr had, as early as 1913, reported successful clinical results which involved the union of a piece of transplanted fascia lata with the cut end of the trapezius muscle on one end and the tendon of the long head of the biceps on the other. Gallie interwove strips of fascia lata into the trapezius muscle and then inserted the ends of the fascia into the humerus, in the treatment of a case of paralysis of the abductors of the arm.

The successful results obtained by Mayer with his improved operation for deltoid paralysis added further evidence to substantiate the claims that transplanted muscle will unite with muscle. In this operation he sutured the piece of transplant to a portion of raised insertion of the trapezius muscle. After preparing a canal just posterior to the acromion process he passed the artificial tendon through it, and downward beneath the deltoid, to a slot in the humerus near the insertion of the deltoid muscle. Mayer's explanation of the principle of his operation is that the pull of the trapezius muscle with its new prolonged fascia insertion holds the head of the humerus firmly into the glenoid cavity. Then as the scapula rotates, the arm being fixed into the glenoid cavity, the arm is carried to the horizontal position. After this the accessory muscles complete the abduction to the vertical position.

Further successful results have been obtained with this operation at the Shriners' Hospital for Crippled Children in San Francisco (Fig. 4). In two of these operations it was found that the fascia tendon, in its passage through the canal in the acromion process, had become adherent to its side, thereby preventing the pull on the humerus. This necessitated a second operation and afforded an opportunity to study the site of union between the muscle and tendon.

REPORT OF CASES

CASE 1.—R. O. Reoperation, three months after original operation. An incision was made into the old operative scar, down through the fat and fascia, to the site of the transplantation.

Operative Findings.—The muscle and transplanted fascia were firmly united. There was a close intermingling of the two tissues, with a gradual grading off into the tissue which resembled a normal tendon. Where the artificial tendon passed through the canal, in the acromion process it was found adherent, on one side, to the bone. The fascia transplant was freed from the bone and a piece of transplanted fat wrapped around the fascia to prevent further adhesions.

CASE 2.—N. A. Reoperation, five months after original Mayer operation. An incision was made into the old operative scar, through the fat and fascia, to the site of the transplantation.

Operative Findings.—The suture line of the fascia and muscle could hardly be distinguished. There was a gradual transition from the muscle to the artificial tendon. The union was very firm. Within the outer layer, where the muscle projected down into the tube, the merging of the two tissues was not so close. The transplanted fascia was found adherent to the sides of the bony canal through the acromion process. The artificial tendon was freed and wrapped with a free graft of fat. A small piece of muscle and fascia was removed at the site of union for miscroscopic study.

Microscopic Findings.—There was a close intermingling of transplanted fascia and muscle. The endomysium and perimysium were closely united to the fascia (Fig. 5). A portion of the muscle close to the line of union was of hyaline-like structure with loss of the cross striations. This same appearance was seen in sections of similar cases in the experimental study. It is possible that the muscle cells proper were undergoing a fibrous transformation and shared in the uniting process. The transplanted fascia was well stained throughout, and in places appeared very much like a normal tendon.

CONCLUSIONS FROM CLINICAL CASES

The results derived from this clinical study prove conclusively that transplanted fascia will unite firmly with muscle.

The microscopical study revealed that there was a close intermingling of the tissues involved and that the most active agents in the uniting process were the perimysium, the endomysium, and the viable cellular elements of the transplanted fascia. There was even a suggestion that the muscle cells themselves may have shared in the process.

SUMMARY

1. Muscle will unite with transplanted fascia.

2. The perimysium and endomysium of the muscle play the major rôle in forming the union with the fibrous tissue element of the fascia.

3. The transplanted fascia seems to engage actively in the process of union.

4. There is some evidence that the muscle cells may undergo a fibrous transformation and share in the union.

Four Fifty Sutter.

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DISCUSSION

JOHN HUNT SHEPHARD, M. D. (Medico-Dental Building, San Jose).—Doctor Haas' experiments and his microscopic studies of the results beautifully show that fascia and muscle will unite when placed in proper apposition.

From a practical point of view, it matters not whether in this union the perimysium and endomysium of the muscle or the muscle cells themselves play the important rôle. Like the debated question of the fate of bone transplants, the desired end is accomplished, though the academic question of the exact part played by the various cells is not completely answered.

The use of fascial strips for suture material in the repair of herniae seems to me to be based upon a misconception of the true function of sutures.

Without entering into a discussion of the relative importance of the proper treatment of the hernial sac and the rearrangement of the fascial relationship, we do desire to secure firm union throughout the entire line of fascial approximation.

Sutures, whether they be of catgut, animal tendons, fascial strips, silk, or silver wire, serve a purpose similar to the screw clamps used by the cabinetmaker in veneering wood, and unless union of the coaptated tissues takes place between the sutures as well as at their site, the union will be very weak. Any non-irritating suture material which will retain the tissues in proper apposition sufficiently long for union to occur accomplishes all that can be asked of it.

I believe that the careful removal of the areolar tissue from the fascia along the line of coaptation, as emphasized by Koontz, is a very important detail in hernial repair.

The use of fascia for the repair of defects in tendons and joint capsules, for the establishment of accessory supporting ligaments or in arthroplasty is another matter.

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Leo Eloesser, M. D. (490 Post Street, San Francisco).—Doctor Haas has again presented us with a careful and interesting piece of work. The evolution from living fascial sutures to preserved ones is curious. It seems to me a rather complicated way of getting back to catgut; for this material, consisting of the tough intestinal submucous tissue, cannot much differ in biologic properties from preserved fascial strips.

I should like to know from Doctor Haas under what tension the fascial strips were implanted, and what part immediate resumption of function has in the fasciomuscular union. Will union persist if the fascia is implanted under a tension considerably greater than that of the normal tendon, or will it give? What becomes of the fascia if no demands are made upon it; if it is attached to the muscle and one end left free?

Many substances seem to unite with muscle in a clinically satisfactory way. Thus Lexor and Eden used tough strips of subcutis.

Doctor Haas' paper gives food for reflection on a number of still unsolved problems.

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Sterling Bunnell, M. D. (516 Sutter Street, San Francisco).—The free fascial or tendon graft has passed the experimental stage sufficiently to be more generally used than it is. Certain aspects, however, are still to be learned, and Doctor Haas' contribution is an excellent one. He has tackled the problem in his usual careful and scientific way and found out the facts for himself. I entirely agree with his conclusions.

From my personal experience in the last fifteen years I have records of four hundred and sixty-one free grafts of fascia and tendon, but have had no experience in using dead prepared fascia. This includes their use in repairing torn ligaments (as in the knee or ankle joints), correcting chronic dislocations, reconstructing crucial ligaments, replacing damaged tendons, connecting muscles to tendons including large tendons (as biceps, hamstrings, and Achilles), repairing annular ligaments and hernias and in tenodesis.

I have frequently exposed these grafts at subsequent operations and determined their condition. In the first few weeks the grafts are swollen and edematous, but later have the normal appearance of fascia or tendon. I am convinced that they live as such though some cells in the depth of the graft may undergo replacement. The surface cells are better located for nutrition during the first week. Practically the grafts have normal appearance and normal function over years and hypertrophy in response to use.

They grow solidly to bone, tendon or muscle if properly contacted. For this no areolar tissue should intervene, and if lateral union is desired the fascia or tendon should be scraped or cut clean. For union with bone an osteoperiosteal contact is necessary. Muscles have a large connective tissue constituent near their tendinous attachment which gives firm union. A lateral union of a belly of an unscraped, untraumatized muscle is weak. A union to the cut end of muscle bundles is strong in proportion to the percentage of connective tissue constituent such as endomysium and perimysium, as muscle itself has very poor regenerative power. Therefore a stronger union results near the end of a muscle, as in Doctor Haas' experiments, than in the fleshy belly. If a natural tendon or a tendon graft is left unattached at one end it will in about two months become swollen, yellowish, brittle and weak from the degeneration of disuse. A tendon or fascial graft which is given the function of resisting repeated tension will hypertrophy in response to the demand. If, however, the force to which it is subjected is too great and too constant, the tissue, whether natural or a graft, will atrophy and yield. In supplying tendon grafts for large muscles, I have found very large grafts to be necessary. Doctors Gallie and Le Mesurier report that under the extreme and constant strain imposed after certain tenodeses about the foot that the tendon yielded. In contrast, tendon grafts in the fingers, which have less constant strain, show a slight tendency to shorten.

In using fascial grafts it is important not to make them in the form of a tube, as the inner surface will have no contact with the surrounding tissue for nourishment by blood and lymph. Serum will collect and the cells lining the uncontacted surface will degenerate. The transmutation of muscle tissue into tendon, as Doctor Haas observed in experiment five, is frequent in the sternocleidomastoid in wry-neck, as shown in the strong cord of tendon found running through the length of the muscle.

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Doctor Haas (Closing).—In Doctor Shephard's discussion he says that the material used for suturing, whether it be catgut, animal tendon, silk or silver wire, is not important as long as the union is ultimately accomplished. However, if the statistics show more successful unions where fascia rather than other suture material has been employed it must be admitted that fascia has advantages over other sutures. Gallie and other operators claim these advantages, both in primary repairs and the treatment of recurrences of cases in which other suture material had been used.

If the live sutures (fascia grafts) take an active share in the uniting process, the advantage in using them is obvious and the analogy between them and the clamps in veneered wood fails to be convincing.

In reply to Doctor Eloesser's questions, the fascia sutures are implanted under very slight tension. When the subject recovers from the anesthetic the tension increases. Function is then established, but in spite of the early use the suture line holds firmly.

In placing the individual sutures, an effort is made to avoid cutting through the muscle fibers in the same manner as one would in closing an abdominal wound or other muscular defect. If the fascia is placed under too much tension there is the chance of a tearing at the line of suture. A fascia strip attached at one end only, will perform in the same manner as a covering fascia, while the fascia under muscle pull develops a tendon-like structure.

The use of preserved fascia has not been covered in this paper. My experimental work on that subject tends to illustrate that it is a less favorable suture material than living fascia. A review of this work has not been published.

I was pleased with Doctor Bunnell's discussion because of his extensive clinical experience in the use of transplanted fascia. After all, it is only by correlating the clinical and experimental results that a definite and practical conclusion may be obtained.